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# Response of Particulate Optical Properties to Coastal Mixing Processes

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## Long-Term Goals

Our long-term goals are to develop a better understanding of the relationships between upper ocean optical properties and particulate and dissolved seawater constituents, and to determine how these relationships are influenced by physical processes. Specific goals include both predicting and modeling optical variability relevant for biological processes, such as phytoplankton photosynthesis, and retrieval of information about the biomass and activity of plankton from optical measurements.

## Scientific/Technical Objectives

Spatial and temporal variability in particulate and dissolved material is a significant source of optical variability in the upper ocean. The primary objective of the present work is to examine the interaction between physical processes and the properties, abundance, and optical significance of different particle types in coastal ocean waters. Specific project objectives are to refine individual particle measurement methods and develop approaches to using individual particle results for interpretation of both inherent and apparent bulk optical properties. The project includes a combination of instrument development and field studies in coastal waters of the eastern US continental shelf.

## Approach

The approach is to use techniques for characterizing and assessing the optical properties of particles using both *in situ* and ship-board instrumentation and both bulk and single particle methods. Our primary tools are flow cytometry for individual particle light scattering and fluorescence properties, spectrophotometry for measuring bulk dissolved and particulate absorption spectra (including separation of phytoplankton pigment absorption from the bulk based on methanol extraction), and spectral underwater radiometry. The flow cytometric and spectrophotometric measurements will be conducted both on discrete water samples and in situ. In situ measurement provides the opportunity for relatively unperturbed sampling, with generally greater spatial resolution, while analysis of discrete water samples continues to provide more detailed characterization of optically-active seawater constituents.

## Tasks Completed

1) We have completed modifications to our existing EPICS flow cytometer, expanding the dynamic range for forward and side angle scattering and chlorophyll

fluorescence measurements by optically dividing and directing the signals to separate photomultipliers with different sensitivities. These modifications are aimed at streamlining sample analysis which previously required separate instrument configurations to cover the particle range of < 1 to ~ 20 microns in diameter. We have also been continuing development of our in situ flow cytometer (independently funded by NSF and DOE), aiming for deployment during the Spring 1997 field program.

2) A large and interesting dataset was collected on the first cruise of this project during August - September 1996. We conducted roughly 3 vertical profiles daily for 3 weeks at the Coastal Mixing and Optics central experiment site on the continental shelf south of Woods Hole. Discrete water sample analysis included complete flow cytometric characterization of the phytoplankton and other particles between approximately 0.7 and 20 microns in diameter. Vertical profiles of spectral downwelling irradiance and upwelling radiance were collected with a free-fall instrument (Satlantic) deployed away from the ship. All instruments performed very well and data analysis is currently underway.

Results

Preliminary analysis of results from the late summer cruise show unexpectedly high levels of day-to-day variability throughout the sampling period, which peaked with the passage of hurricane Eduoard through the study site. The decrease in stratification following the hurricane was accompanied by changes in the optical properties of the water column (Fig. 1), attributable primarily to changes in the abundance and characteristics of suspended material.

Flow cytometric analysis of particle properties (Fig. 2) on the day before the hurricane indicated that at the surface, phytoplankton and non-fluorescent particles accounted for nearly equal amounts of forward light scattering. Light scattering in the chlorophyll maximum layer (27 m) was dominated by phytoplankton, and near the bottom, phytoplankton were much less important and non-fluorescent particles much more, as expected.

During the hurricane the water column may have mixed completely, although two days afterwards, when we sampled the site again, both hydrography and particle distributions were showing evidence of re-stratification. The size distributions of light scattering by phytoplankton at the surface and at 20 m, for example, were dramatically different, with a large increase in the ultraphytoplankton (2-5 μm cells) at the surface. In addition, the size distributions were markedly different from those of the previous sampling: Cells at the large end of the size distribution (>10 μm) had become relatively less abundant, and at the surface the smallest cells (*Synechococcus*) had increased in size.

After the hurricane, non-fluorescent particles had become the major contributors to light scattering in the chlorophyll maximum layer as well as near the bottom; at the surface there was almost no change. In the subsurface samples, the size distribution of the non-fluorescent particles was shifted dramatically to smaller sizes, from a mode of about 10 μm to about 2 μm.

This is an example of the type of analysis which we will be pursuing for our entire data set, spanning a 3 week time period and including several profiles each day.

## Impacts for Science and Technology and/or Applications

This project includes the development of improved techniques for analyzing marine particles and characterizing their optical properties. Our ability to independently quantify size distributions for phytoplankton and non-phytoplankton particles is a new contribution which will lead to better understanding of optical variability in the ocean.

## Relationships to Other Projects

This project is closely tied to Sosik's NASA New Investigator Program award. The NASA support will be used to investigate the regulation of local biological production of particles at the CMO site and to explore the effects of changes in particle properties on ocean color. In addition, Olson is independently funded (DOE, NSF) to develop an in situ flow cytometer which will be deployed at the CMO site on future cruises. The interpretation of flow cytometric light scattering and fluorescence distributions is also being supported by Olson's NSF JGOFS project for work in the Arabian Sea.

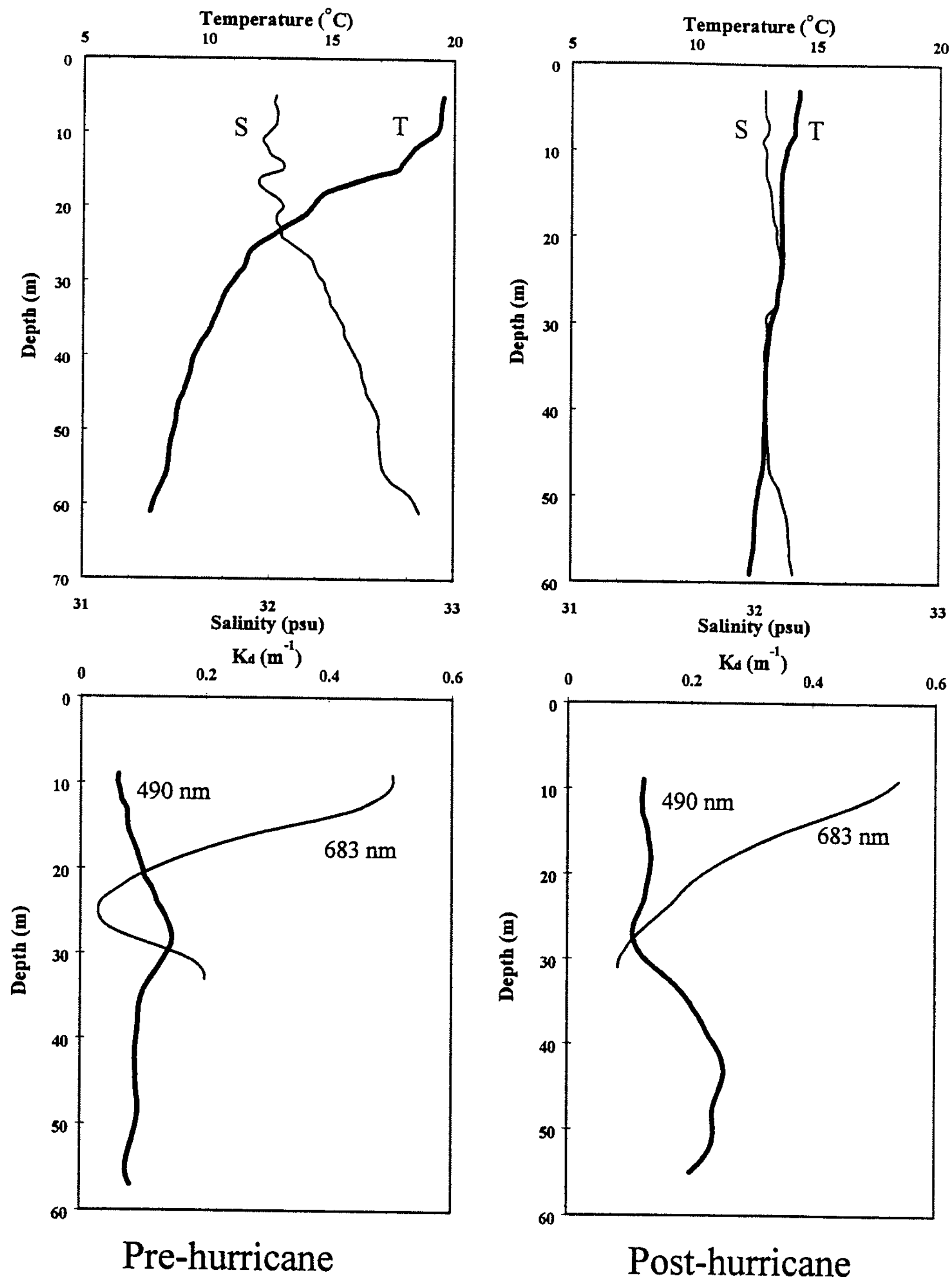


Figure 1. Hydrographic and optical data collected on the first CMO Optics cruise at stations near the central mooring site (~65 m water depth), before (August 31) and after (September 4) the passage of hurricane Eduoard. Vertical distributions of temperature and salinity were relatively uniform after the hurricane, but variations in diffuse attenuation were high. The subsurface peak in $K_d$ at 490 nm on August 31 is associated with phytoplankton, as indicated by the pronounced minimum in $K_d$ at 683 nm (due to chlorophyll fluorescence), while the high attenuation near the bottom on September 4 is due to resuspended material from the bottom.

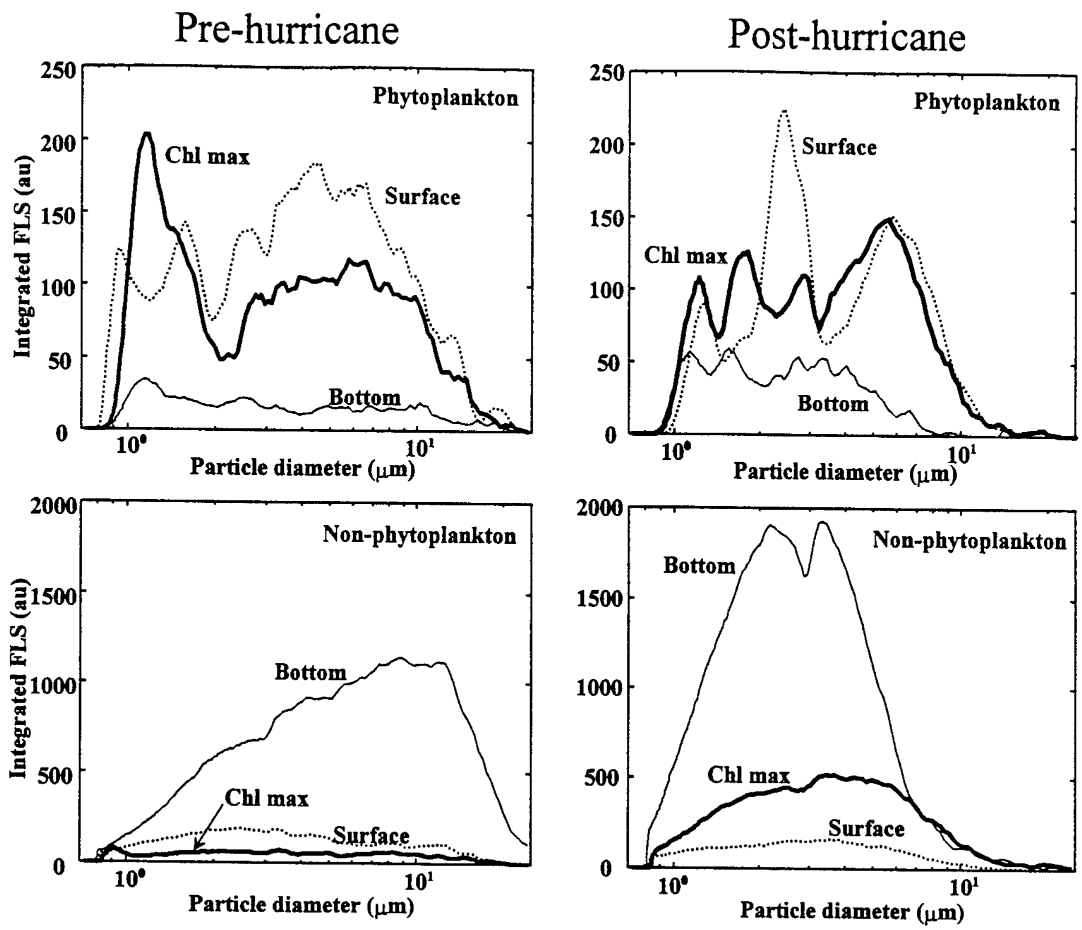


Figure 2. Particle size distributions for phytoplankton and non-phytoplankton showing relative contributions to forward light scattering (FLS), as measured by the flow cytometer. Water was collected from discrete depths for the same 2 days as in Figure 1 and approximately 5 ml samples were analyzed. FLS values are expressed in comparable arbitrary units in all cases. Note the change in scale for the non-phytoplankton particles.

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Spatial and temporal variability in particulate and dissolved material is a significant source of optical variability in the upper ocean. The goal of this project is to examine the interaction between physical processes and the properties, abundance, and optical significance of different particle types in coastal ocean waters. Specific project objectives are to refine individual particle measurement methods and develop approaches to use individual particle results for interpretation of both inherent and apparent bulk optical properties. The project includes a combination of instrument development and field studies in waters of the eastern US continental shelf as part of the Coastal Mixing and Optics Accelerated Research Initiative. Techniques including bulk absorption measurements and individual particle analysis are being used and sampling includes a combination of *in situ* measurements and ship-board analysis of water. Absorption is evaluated as a function of categories distinguished based on filtration (particulate vs. dissolved) and by chemical methods (phytoplankton vs. detritus). Distributions of particle size and scattering are determined for various particle types (including phytoplankton and non-phytoplankton) which can be distinguished by their flow cytometric fluorescence and scattering properties. A 10-month experiment is currently underway, with one 3-week cruise completed and a second planned for April-May, 1997.

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